

National Aeronautics and Space Administration

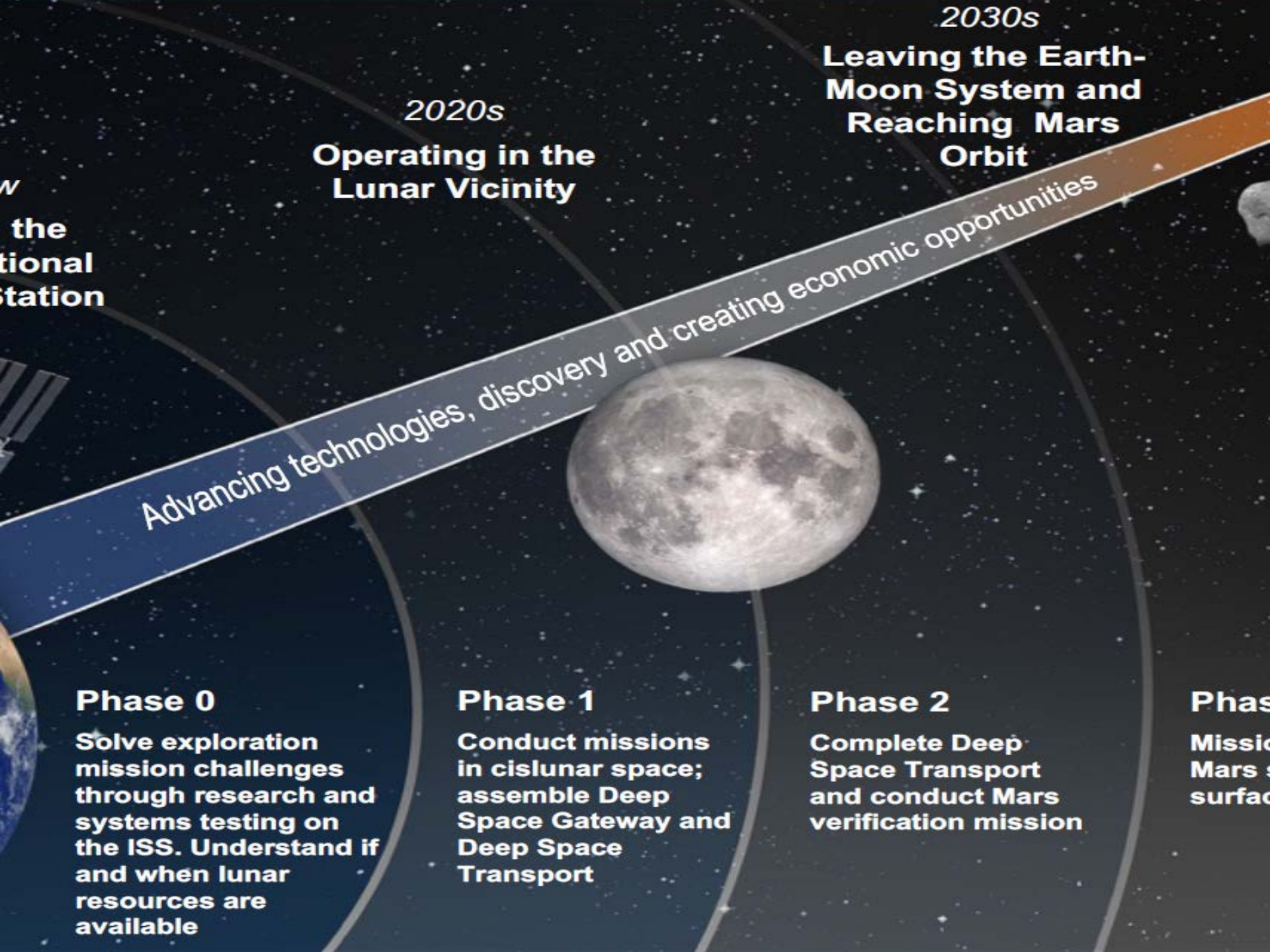


Moon/Mars Life Support Systems – How far along are we?

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National Aeronautics and Space Administration

24 Mai 2017

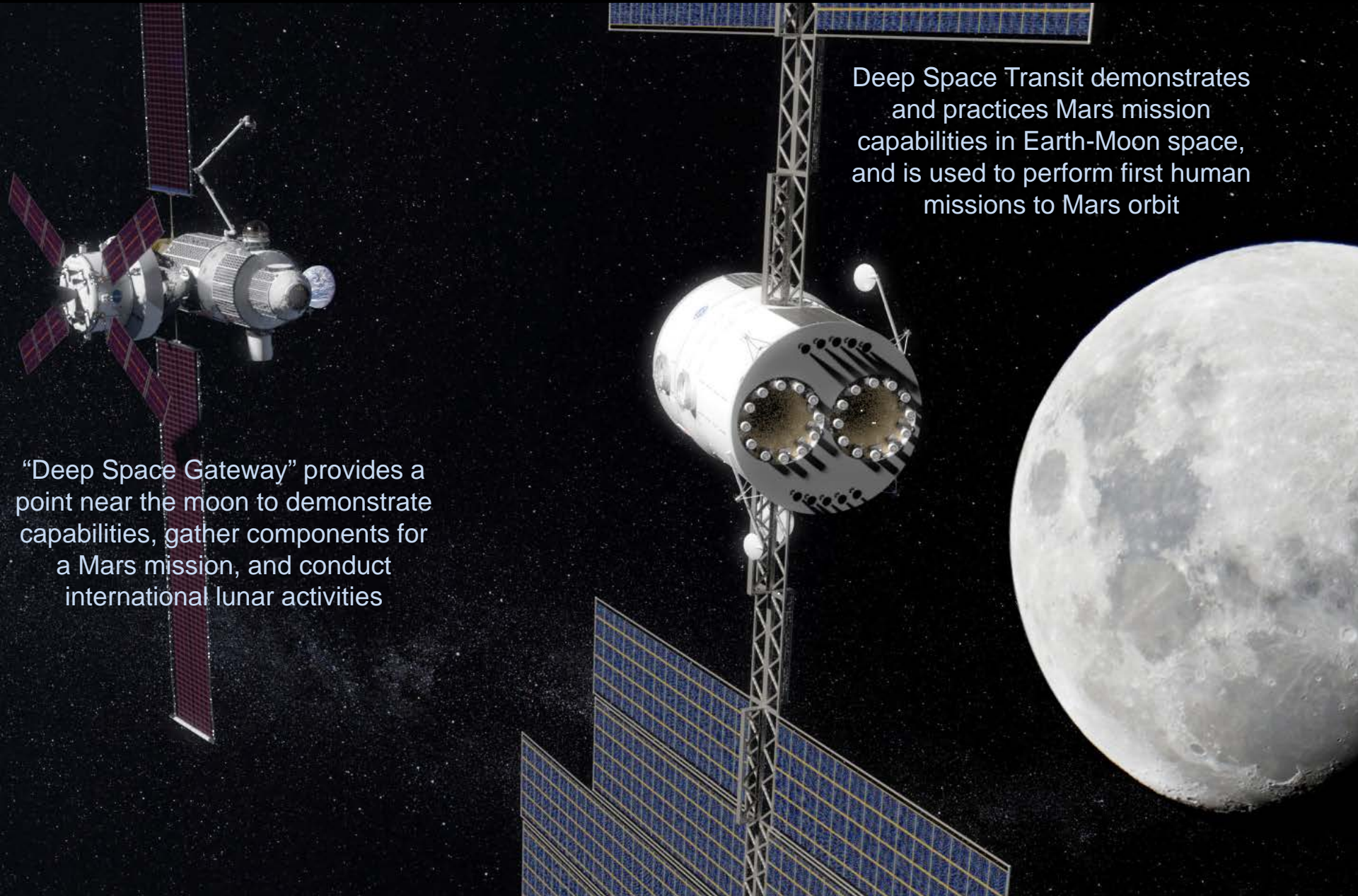


Concepts for New Vehicles Require New Systems

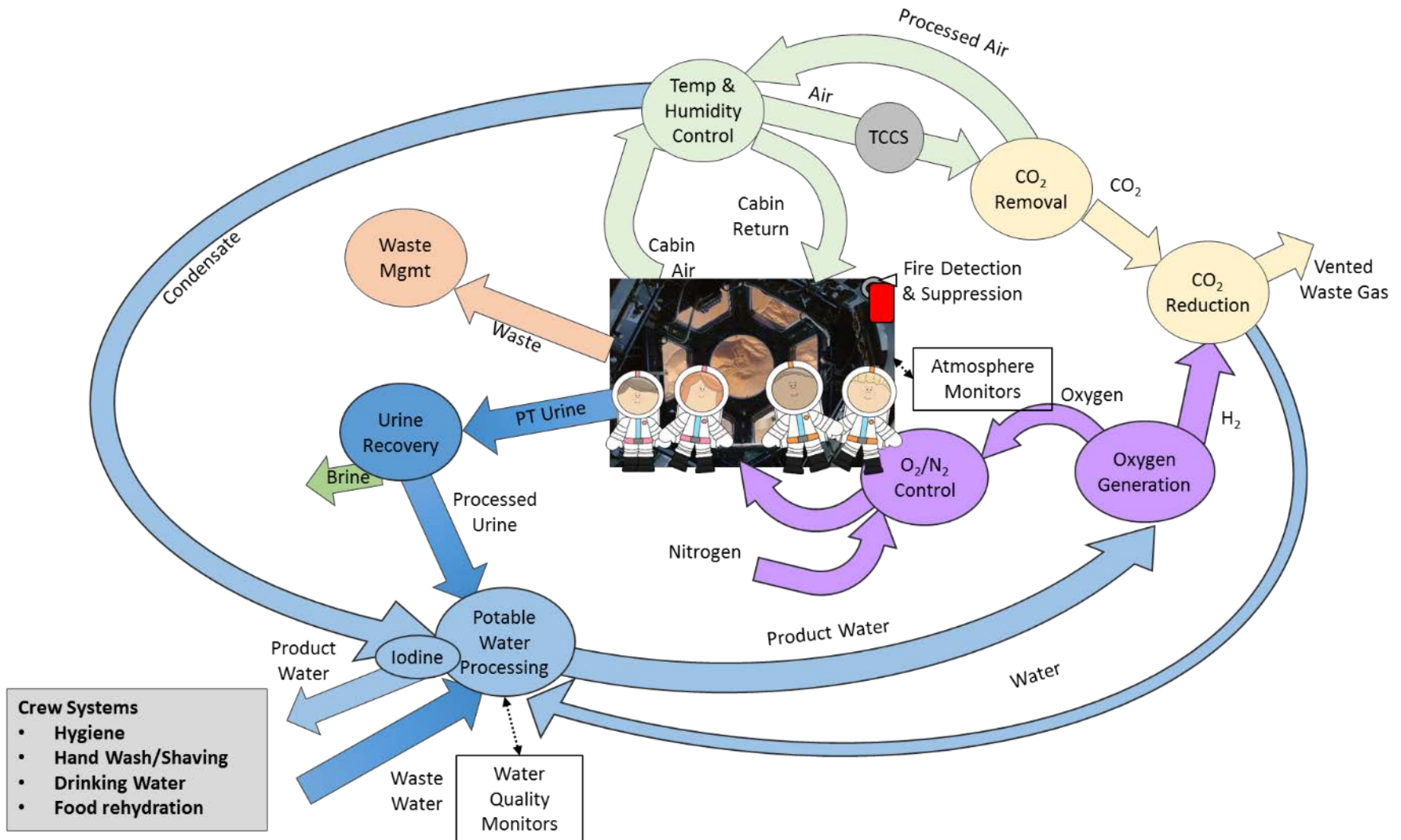


Deep Space Transit demonstrates and practices Mars mission capabilities in Earth-Moon space, and is used to perform first human missions to Mars orbit

"Deep Space Gateway" provides a point near the moon to demonstrate capabilities, gather components for a Mars mission, and conduct international lunar activities



Experience in Closed-Loop Life Support

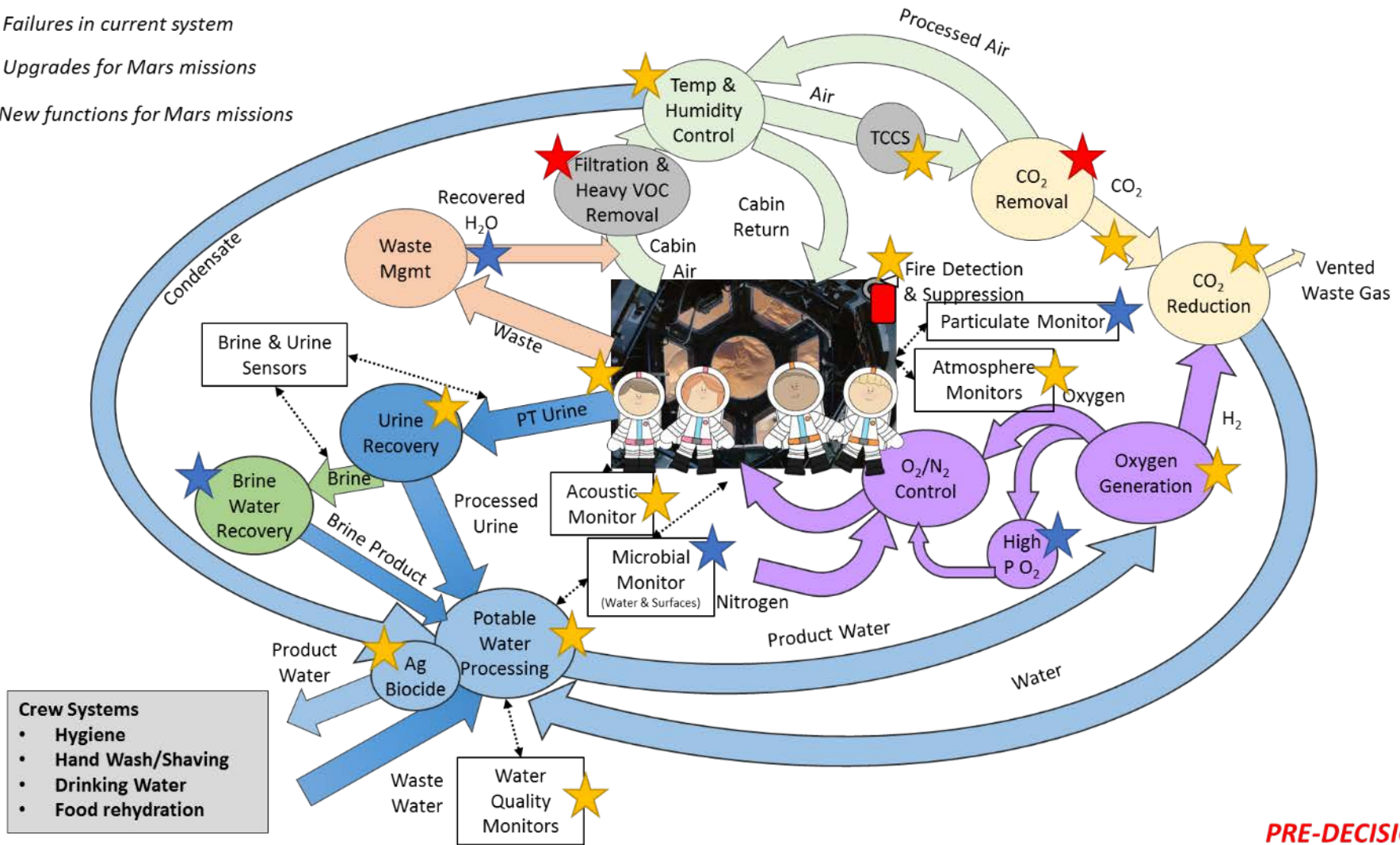


- Humans need the same things to keep them healthy no matter where they are.
- Design technologies and systems to find the most efficient, cost effective, and reliable way to meet those needs.
- The right answer varies depending on the mission and vehicle.
- Life support systems for long duration missions are very interconnected

Evolution of Life Support Systems



- ★ Failures in current system
- ★ Upgrades for Mars missions
- ★ New functions for Mars missions



PRE-DECISIONAL

- Nearly every function in the system will be updated because of lessons learned in previous spaceflight missions and new technology developments
- These will make the crew more self-sufficient for future missions, by recycling more waste materials, and having more information on their own systems

Current ISS Capabilities and Challenges: Atmosphere Management



- **Circulation**

- ISS: Fans (cabin & intermodule), valves, ducting, mufflers, expendable HEPA filter elements
- **Challenges: Quiet fans, filters for surface dust**

- **Remove CO₂ and contaminants**

- ISS: Regenerative zeolite CDRA, supports ~2.3 mmHg ppCO₂ for 4 crew. MTBF <6 months. Obsolete contaminant sorbents.
- **Challenges: Reliability, ppCO₂ <2 mmHg, commercial sorbents**

- **Remove humidity**

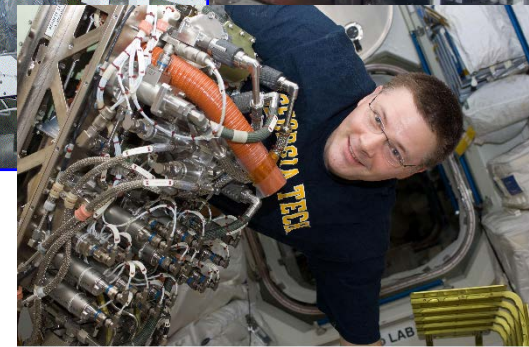
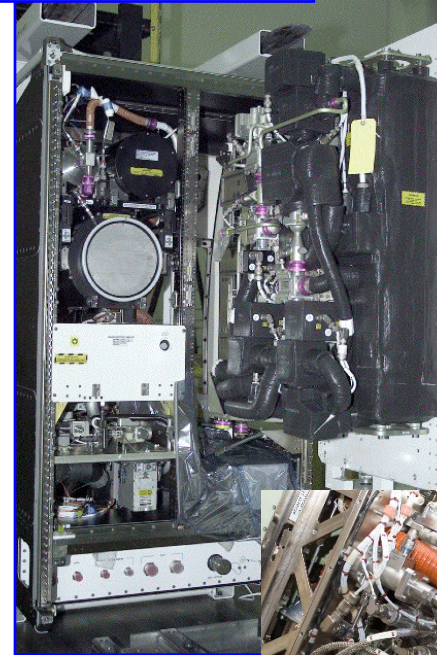
- ISS: Condensing heat exchangers with anti-microbial hydrophilic coatings requiring periodic dryout, catalyze siloxane compounds.
- **Challenge: Durable, inert, anti-microbial coatings that do not require dry-out**

- **Supply O₂**

- ISS: Oxygen Generation Assembly (H₂O electrolysis, ambient pressure); high pressure stored O₂ for EVA
- **Challenge: Provide high pressure/high purity O₂ for EVA replenishment & medical use**

- **Recovery of O₂ from CO₂**

- ISS: Sabatier process reactor, recovers 42% O₂ from CO₂
- **Challenge: >75% recovery of O₂ from CO₂**



Current ISS Capabilities and Challenges: Water Management

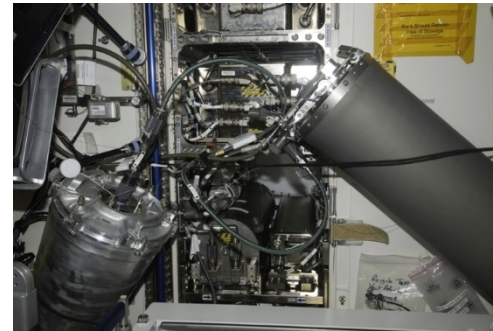


• Water Storage & biocide

- ISS: Bellows tanks, collapsible bags, iodine for microbial control
- **Challenges:** Common biocide (silver) that does not need to be removed prior to crew consumption; dormancy

• Urine Processing

- ISS: Urine Processing Assembly (vapor compression distillation), currently recovers 80% (brine is stored for disposal)
- **Challenges:** 85-90% recovery (expected with alt pretreat formulation just implemented); reliability; recovery of urine brine water



• Water Processing

- ISS: Water Processor Assembly (filtration, adsorption, ion exchange, catalytic oxidation, gas/liquid membrane separators), 100% recovery, 0.11 lbs consumables + limited life hw/lb water processed.
- **Challenges:** Reduced expendables; reliability

Current ISS Capabilities and Challenges: Waste Management



- **Logistical Waste (packaging, containers, etc.)**
 - ISS: Gather & store; dispose (in re-entry craft)
 - **Challenge: Reduce &/or repurpose**
- **Trash**
 - ISS: Gather & store; dispose (in re-entry craft)
 - **Challenge: Compaction, stabilization, resource recovery**
- **Metabolic Waste**
 - ISS: Russian Commode, sealed canister, disposal in re-entry craft
 - **Challenge: Long-duration stabilization, potential resource recovery, volume and expendable reduction**



Current ISS Capabilities and Challenges: Environmental Monitoring



• Water Monitoring

- ISS: On-line conductivity; Off-line total organic carbon, iodine; Samples returned to earth for full analysis
- **Challenge:** On-orbit identification and quantification of specific organic, inorganic compounds.

• Microbial

- ISS: Culture-based plate count, no identification, 1.7 hrs crew time/sample, 48 hr response time; samples returned to earth.
- **Challenge:** On-orbit, non culture-based monitor with identification & quantification, faster response time and minimal crew time

• Atmosphere

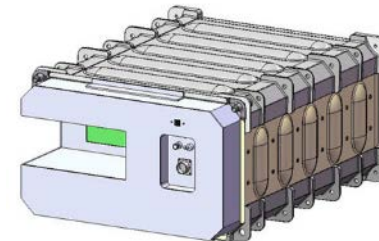
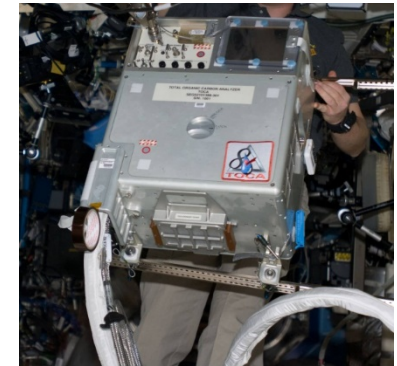
- ISS: Major Constituent Analyzer (mass spectrometry – 6 constituents); COTS Atmosphere Quality Monitors (GC/DMS) measure ammonia and some additional trace gases; remainder of trace gases via grab sample return; Combustion Product Analyzer (CSA-CP, parts now obsolete)
- **Challenges:** On-board trace gas capability that does not rely on sample return, optical targeted gas analyzer

• Particulate

- ISS: N/A
- **Challenge:** On-orbit monitor for respiratory particulate hazards

• Acoustic

- SOA: Hand held sound level meter, manual crew assays
- **Challenge:** Continuous acoustic monitoring with alerting



Brine Water Processing to Recover More Water



IWP Brine
Processing Bag



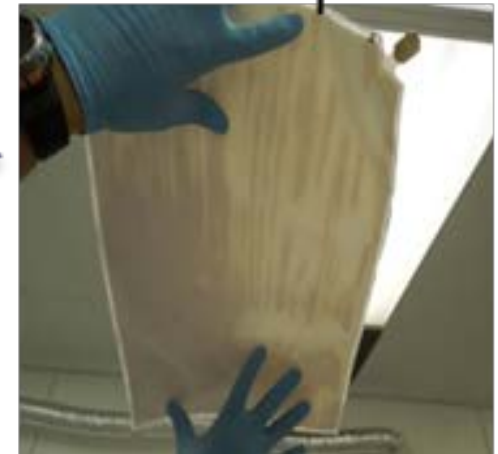
PARAGON
SPACE DEVELOPMENT CORPORATION



Water



Safe Disposal





Air Revitalization to Recover More Oxygen

Electrolysis Reaction



Sabatier Reaction



Conclusion:

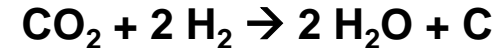
- It takes 4 H₂ to make 2 H₂O, but you only get 2 H₂ back when you split H₂O to make O₂.
- You can't repeat the cycle 100% because you lost H₂, so you have to vent unreacted CO₂ which wastes oxygen.

How can we recycle more? What challenges does that create?

Carbon Formation from Methane



Bosch Reactions



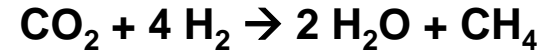
Air Revitalization to Recover More Oxygen



Electrolysis Reaction



Sabatier Reaction



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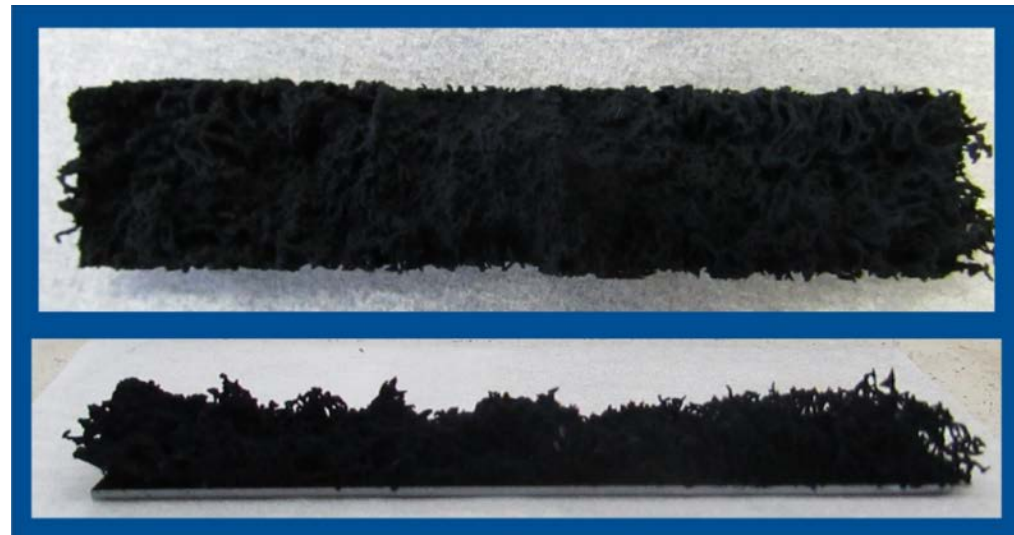
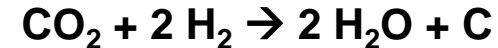
- It takes 4 H_2 to make 2 H_2O , but you only get 2 H_2 back when you split H_2O to make O_2 .
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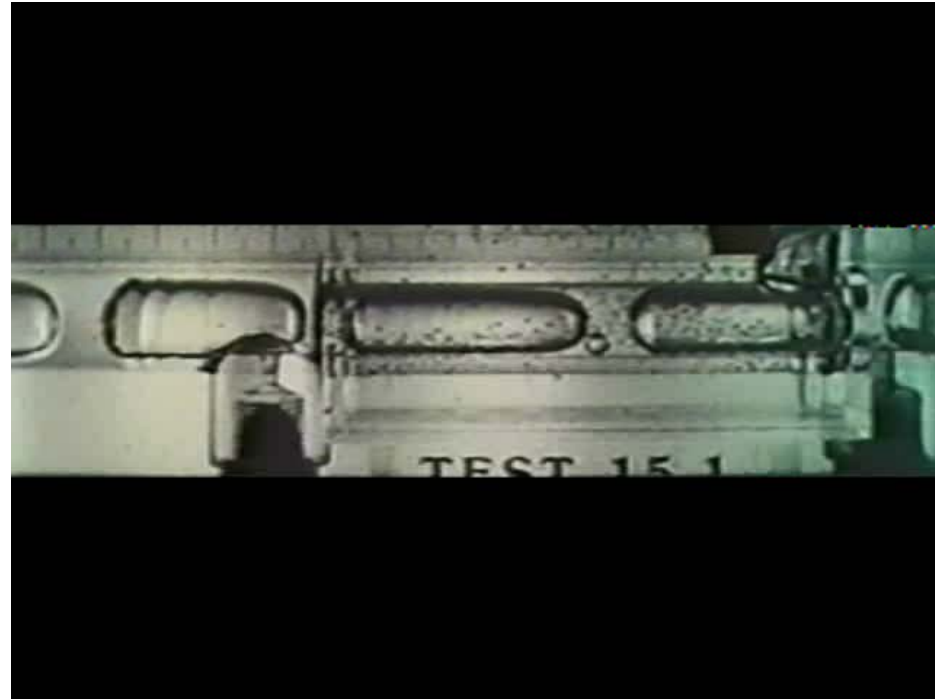
Carbon Formation from Methane



Bosch Reactions



Microgravity Science Can Lead to Innovation



Each movie has the same inlet flow: Alternating pulses of water and air

Surface tension vs gravity!

Steps from Science to Design



Steps from Science to Design



Condensing Heat Exchanger

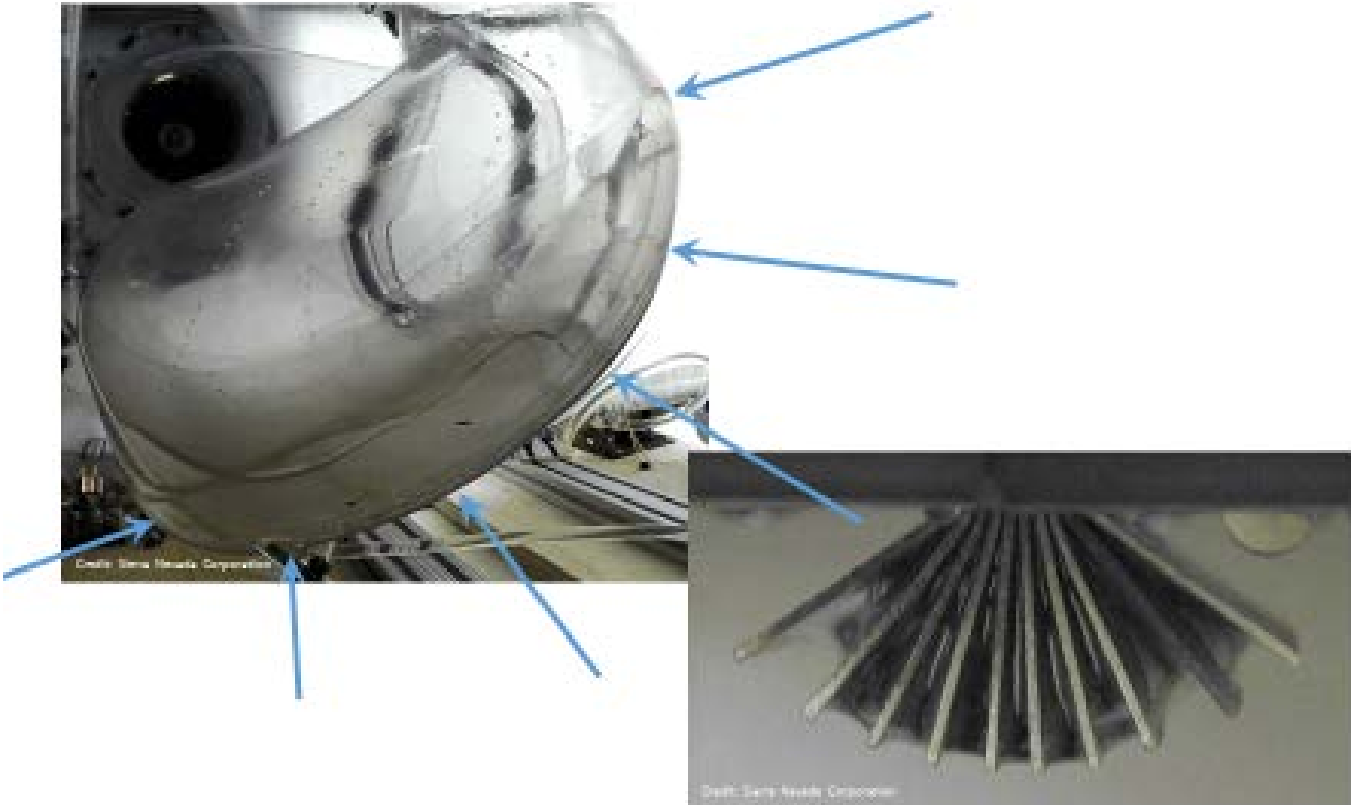


Spaceflight condensing heat exchangers:

- Use hydrophilic coating to keep water attached to surface by surface tension, but coating wears out over time
- Suck the water through holes in the heat exchanger
- Do not let water droplets get carried into the air revitalization system!

Using Capillary Effects for Fluid Retention

Water Spread Along Vertex of Reservoir in Microgravity
During Zero-Gravity Parabolic Test Flight



What if you didn't have to worry about where the droplets of water went?

Logistics & Waste Processing



ISS stores trash it burns in Earth's atmosphere when cargo vehicles leave

Logistics & Waste Processing



ISS stores trash it burns in Earth's atmosphere when cargo vehicles leave

What should we do for the future?

- Drying?
- Compaction?
- Destruction?



Figure 6. Top: Photograph of a sample of undried (50 % moisture) fecal simulant (left) and a torrefied sample (right), heated to a maximum temperature of ~ 250 °C. Bottom: Photograph of a sample of fresh canine feces (left) and a torrefied sample (right). The torrefied sample was heated to a maximum temperature of ~250 °C and gently crushed.

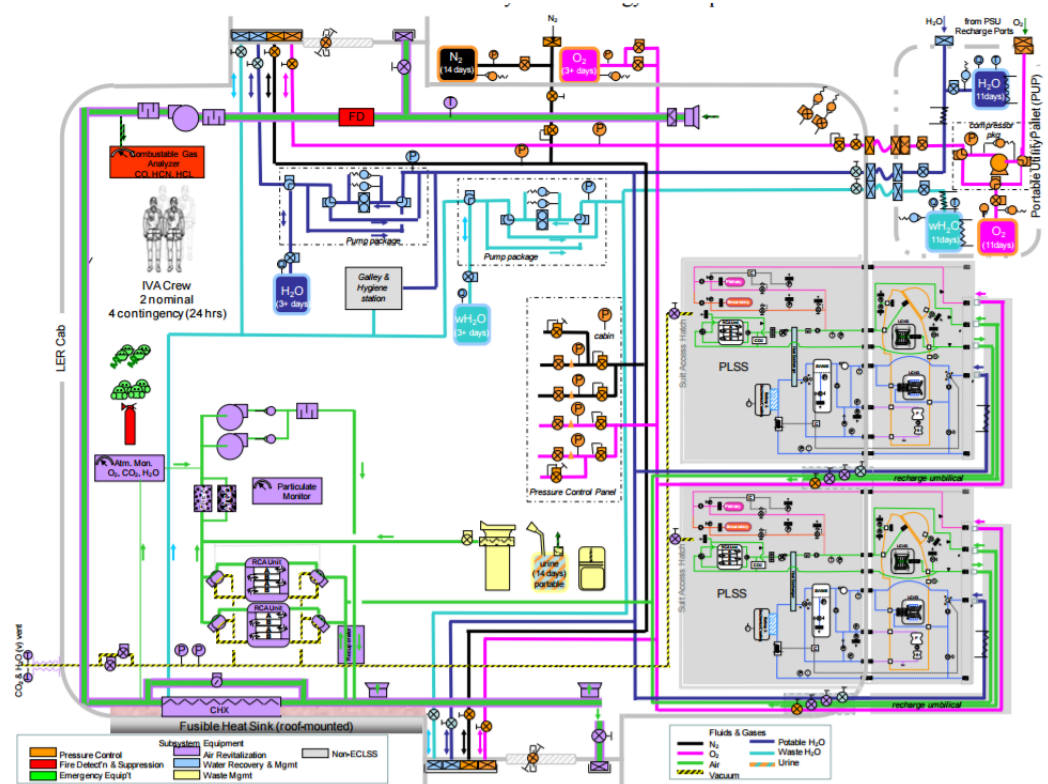
Life Support in Short Duration Vehicles



Orion Suit Loop: Shared life support in cabin air, or spacesuits to survive 6-day emergency return home if the vehicle cabin loses pressure

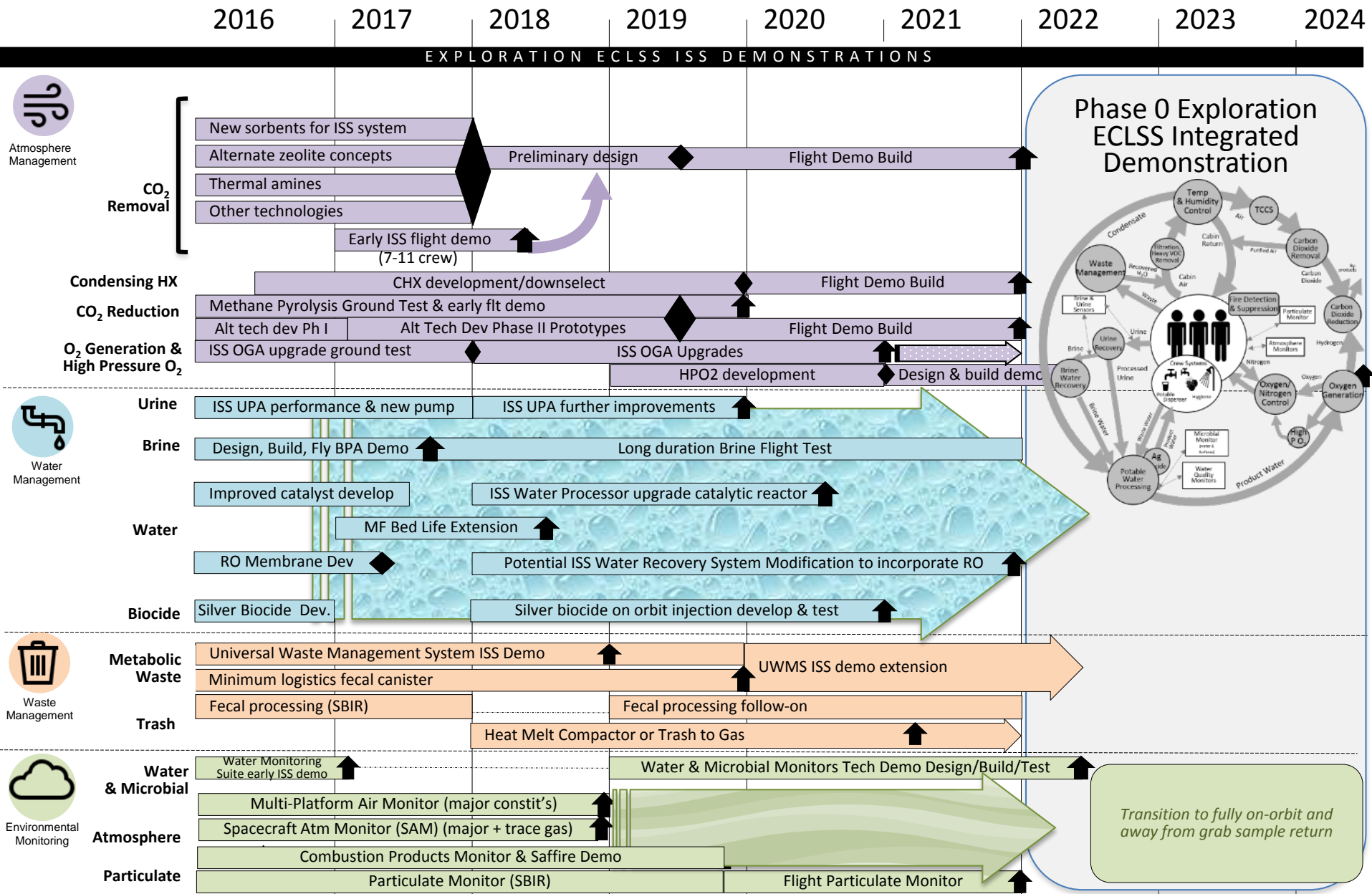


Pressurized Rovers



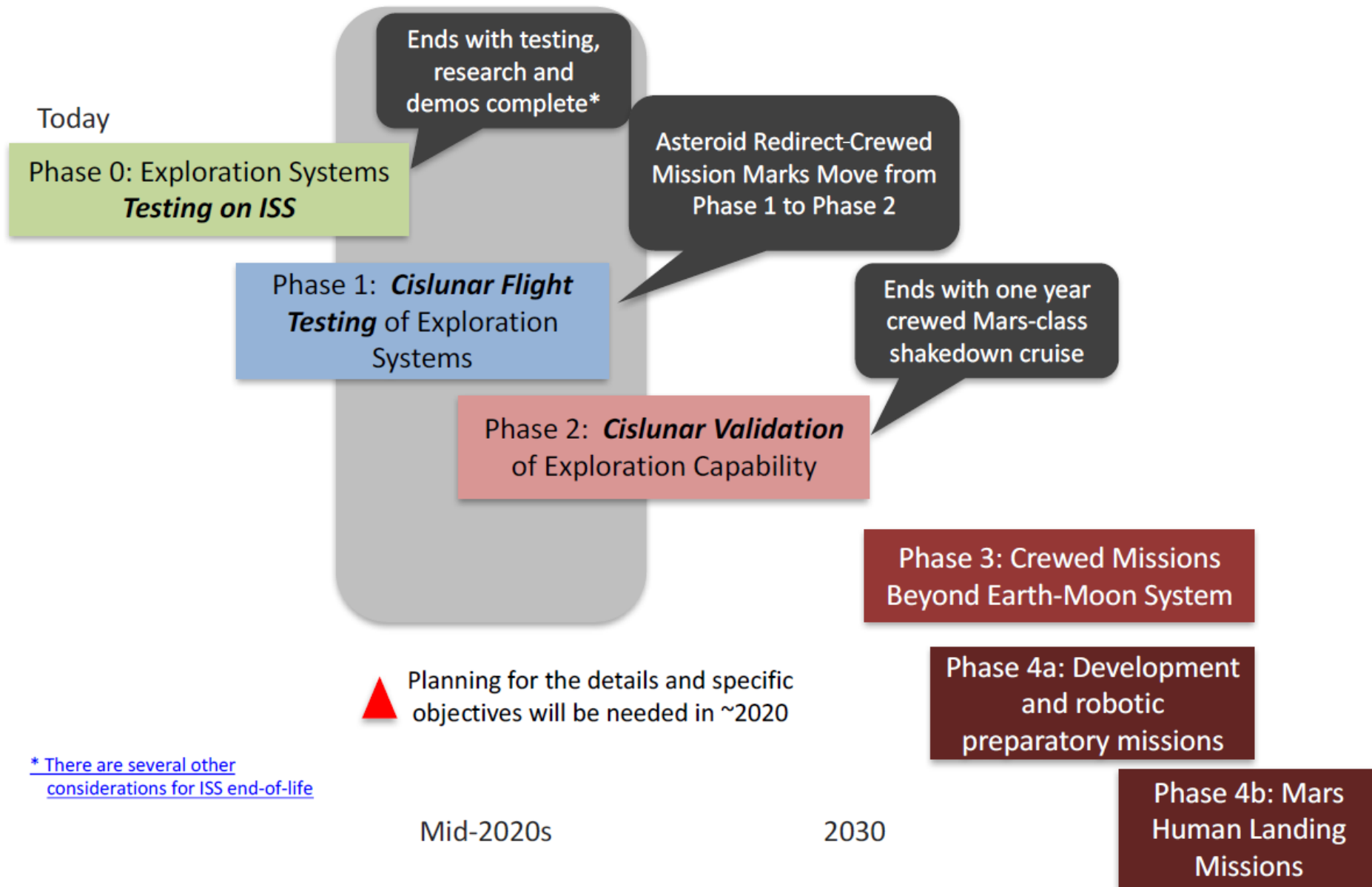
- Even small,

When Will We Be Ready?

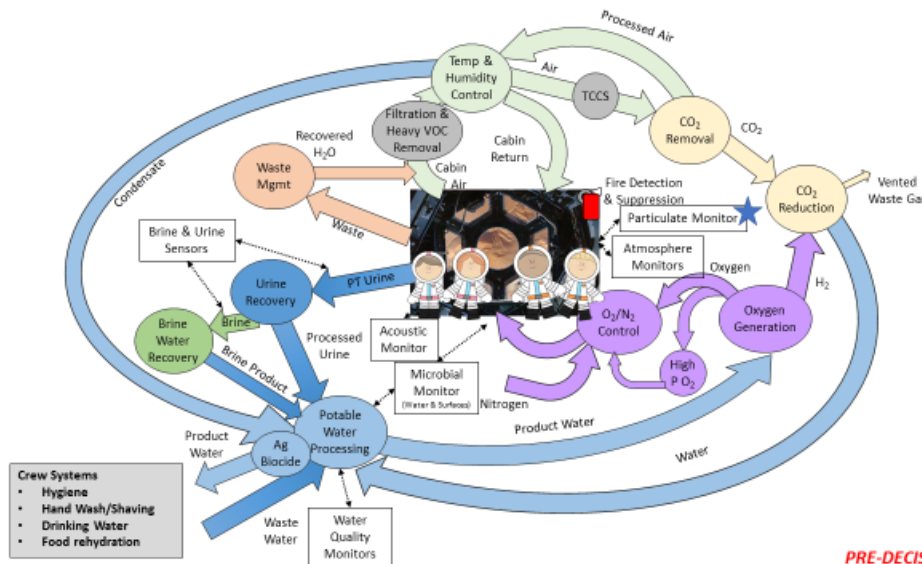




Human Space Exploration Phases From ISS to the Surface of Mars as of November 2016



Life Support & Biological Systems



Earth has Buffers

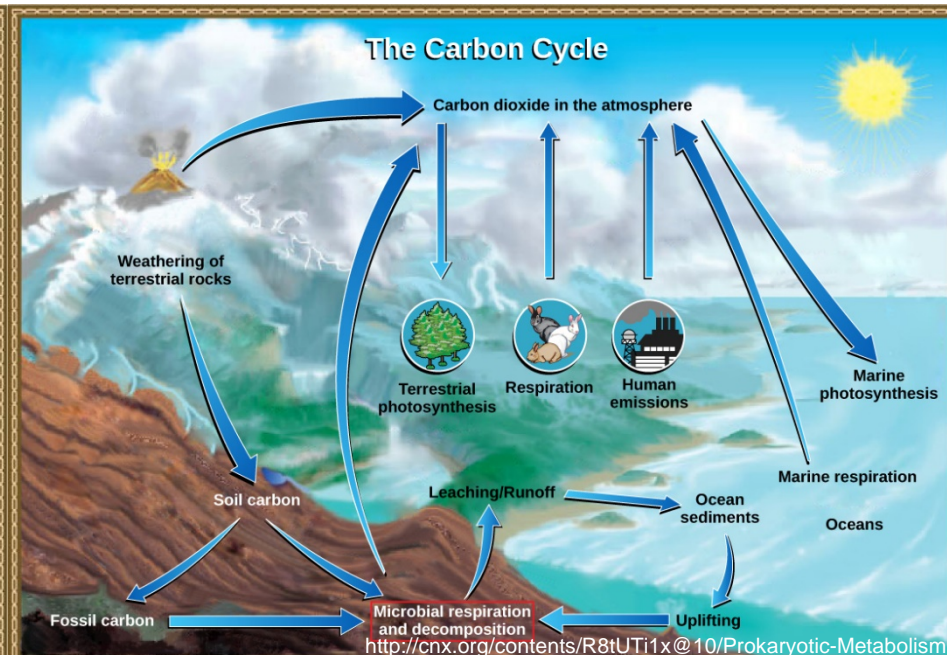
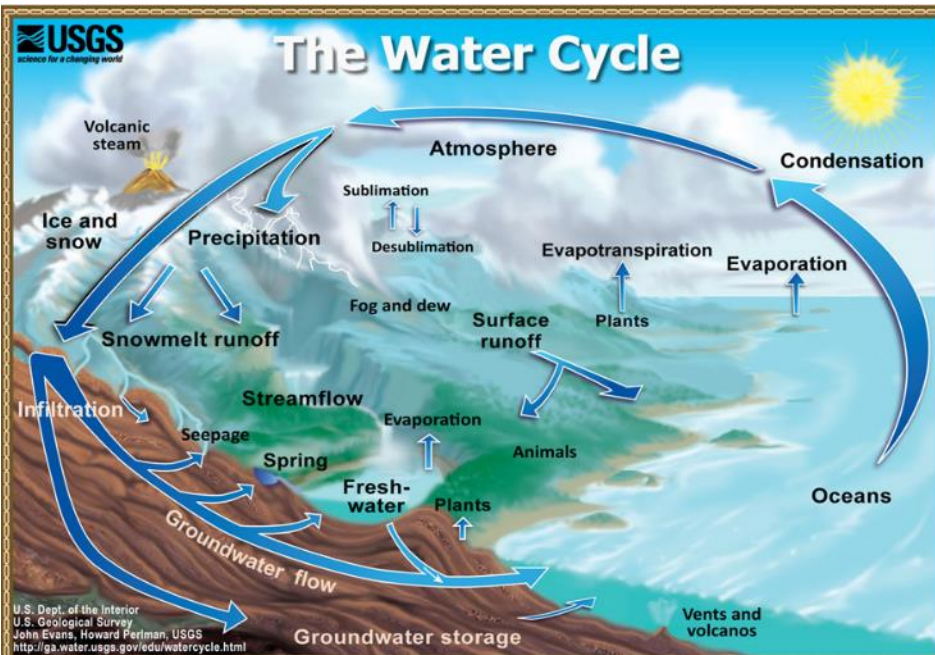
Earth = 510 km² surface area, 2m tall
 1 x 10¹⁵ m³ shared by 7.5 Billion People
 → 136,000 m³ per person on Earth
 (Not including ocean depths or atmosphere thickness)

Future spacecraft volume ~25 m³/person

Changes are felt very fast!

Processing equipment must be small!

PRE-DECISIONAL



Biological Water Processor



How do we take advantage of biological processes in microgravity?

Biological Water Processor



How do we take advantage of biological processes in microgravity?

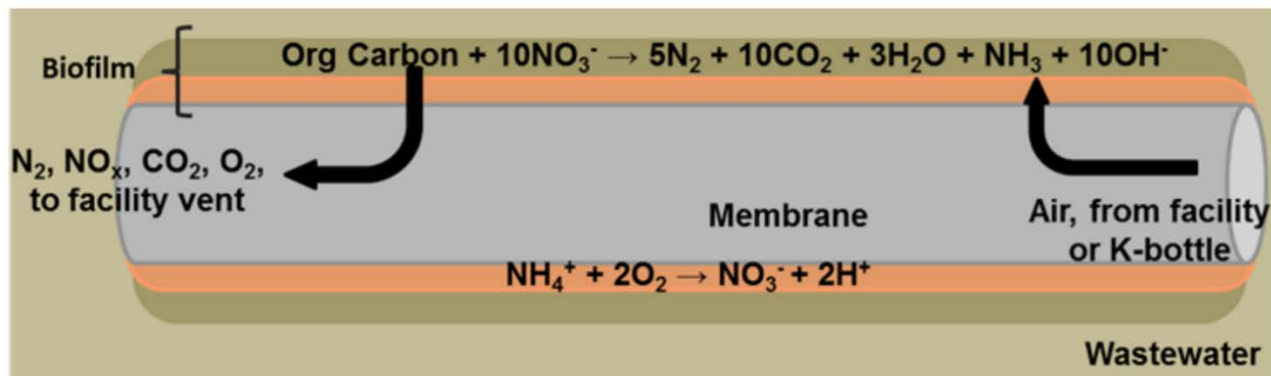
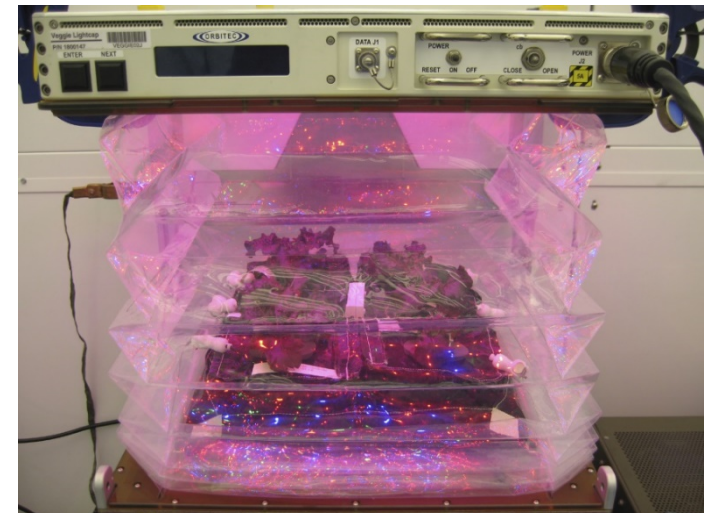
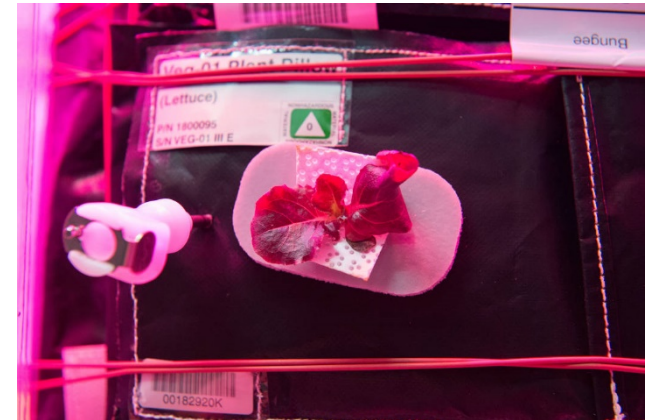


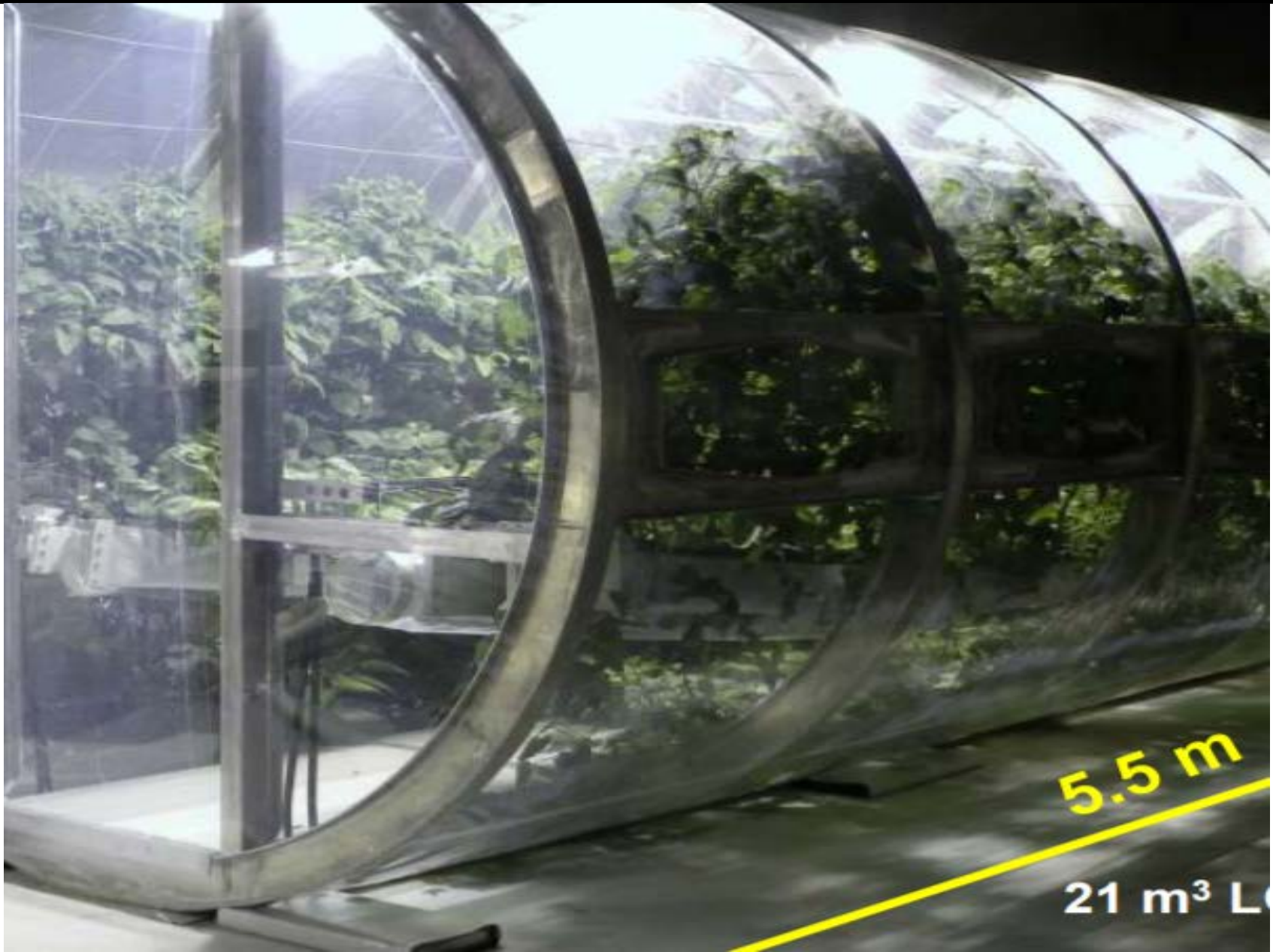
Figure 2. Biological reactions occurring at the surface of the membrane and in the biofilm



VEGGIE

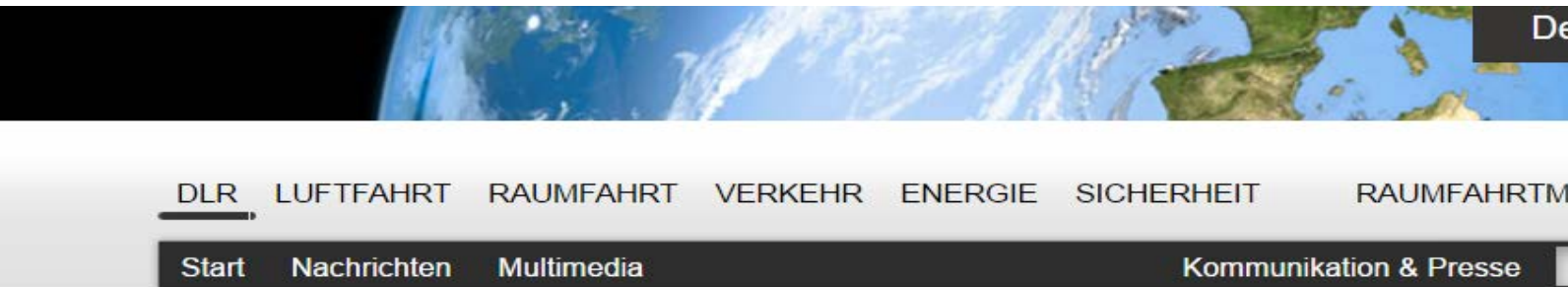


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Eu:CROPIS: Tomatenzucht im Weltall

Donnerstag, 24. April 2014



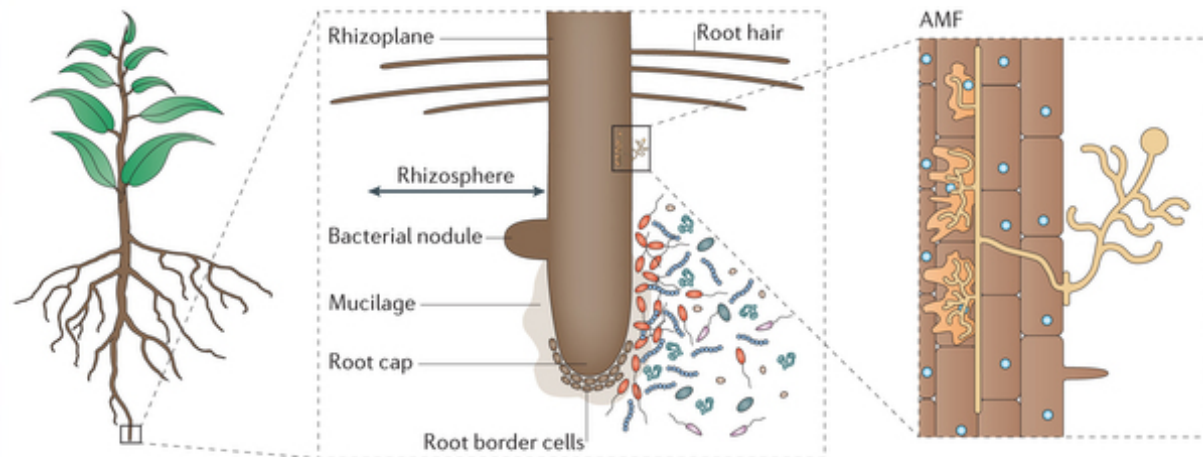
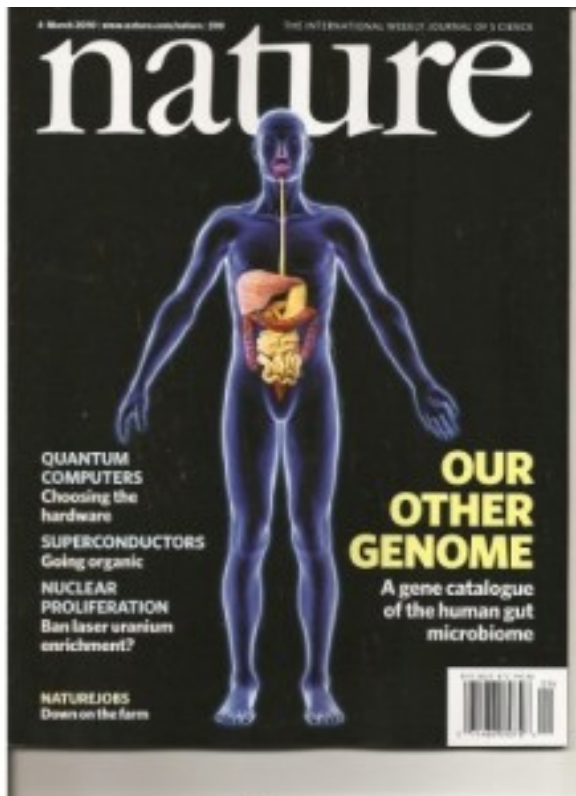
New Technology, New Information, New Questions



THE NATIONAL MICROBIOME INITIATIVE



Oxford Nanopore MinION Sequencer



One Step at a Time!



Mars Greenhouse

Questions?

